US010568173B1

(12) United States Patent
Hsu et al.

(10) Patent No.: US 10,568,173 B1
(45) Date of Patent: Feb. 18, 2020

(54) **DIMMER CIRCUIT FOR USE IN LIGHT-EMITTING DIODE LIGHTING SYSTEM**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/231,317**

(22) Filed: **Dec. 21, 2018**

(51) **Int. Cl.**
H05B 33/08 (2006.01)
H05B 37/02 (2006.01)

(52) **U.S. Cl.**
CPC ***H05B 33/0845*** (2013.01); ***H05B 33/0815*** (2013.01); ***H05B 37/0281*** (2013.01)

(58) **Field of Classification Search**
CPC H05B 33/0815; H05B 33/0818; H05B 37/0845; H05B 33/0884; H05B 33/0809; H05B 33/0848; H05B 33/0896; H05B 37/0245; H05B 37/0254; H05B 33/0863; H05B 33/0872; H05B 33/0803; H05B 37/0272; H05B 33/0857; H05B 33/0887
See application file for complete search history.

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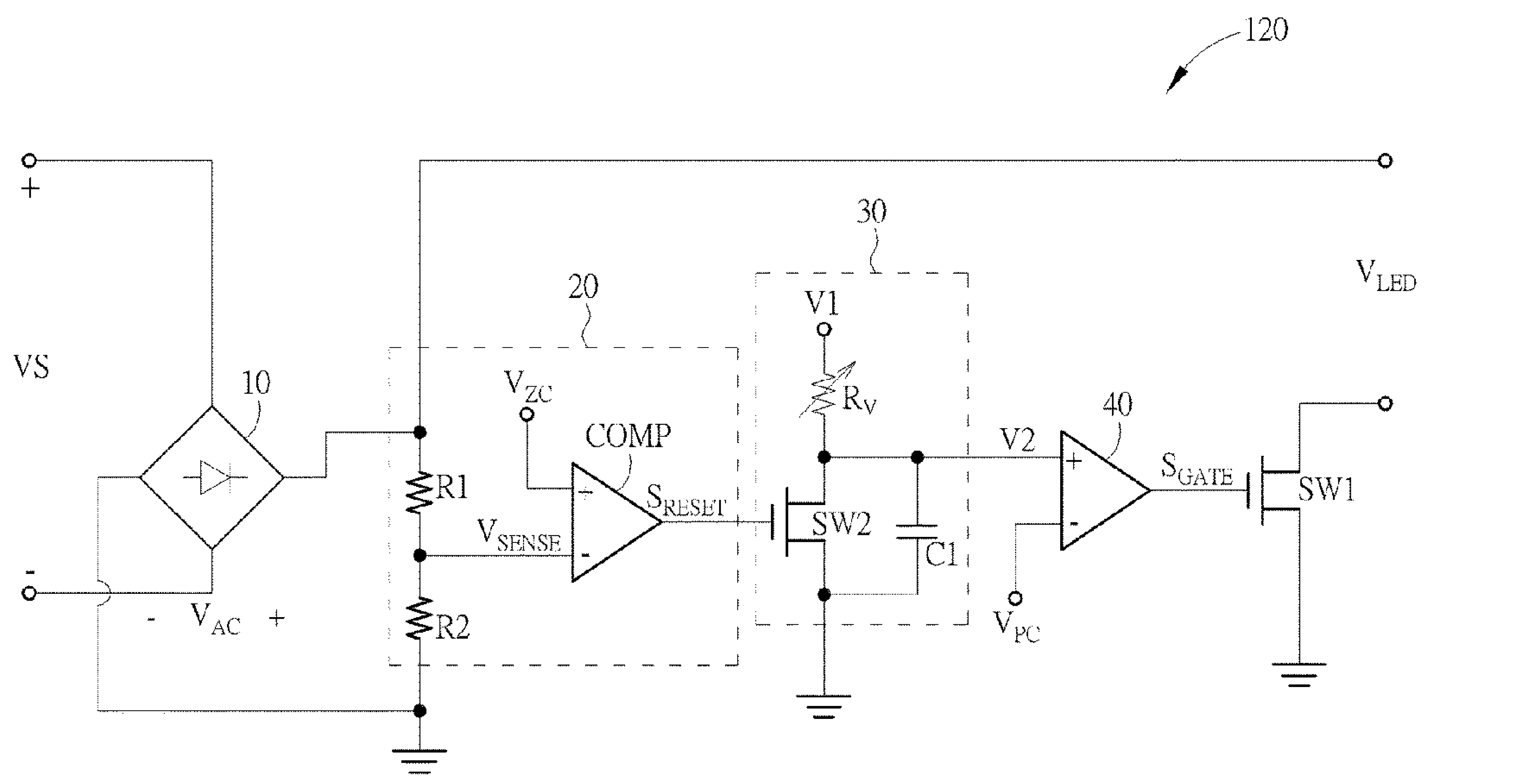
(57) **ABSTRACT**

A dimmer circuit is used in an LED lighting system which includes a power supply circuit and a lamp. The power supply circuit is configured to provide an AC voltage. The lamp is coupled to the power supply. The dimmer circuit is configured to adjust the brightness of the lamp according to a dimming signal without the lamp conducting a bleeder current during each cycle of the AC voltage.

3 Claims, 6 Drawing Sheets



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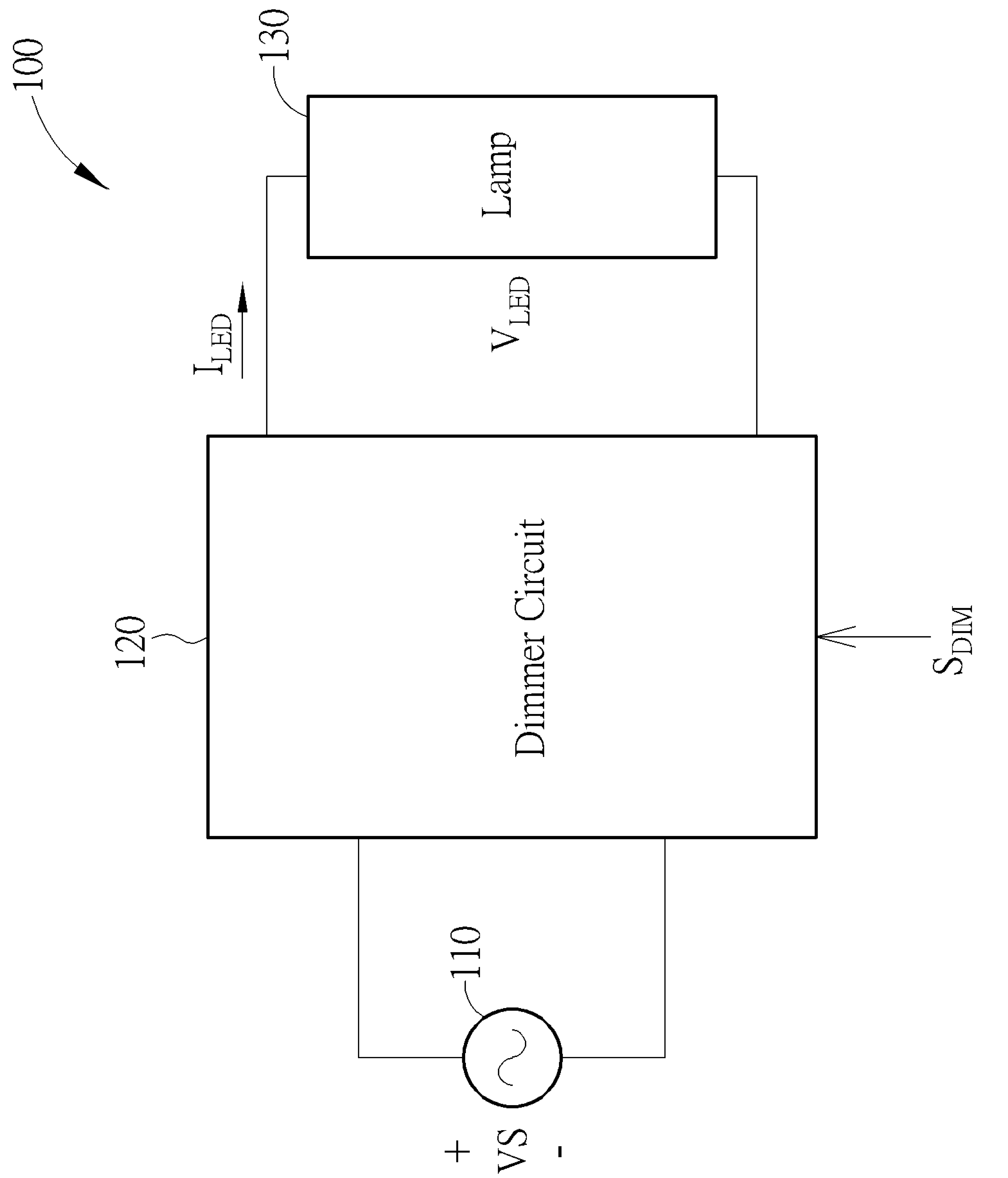
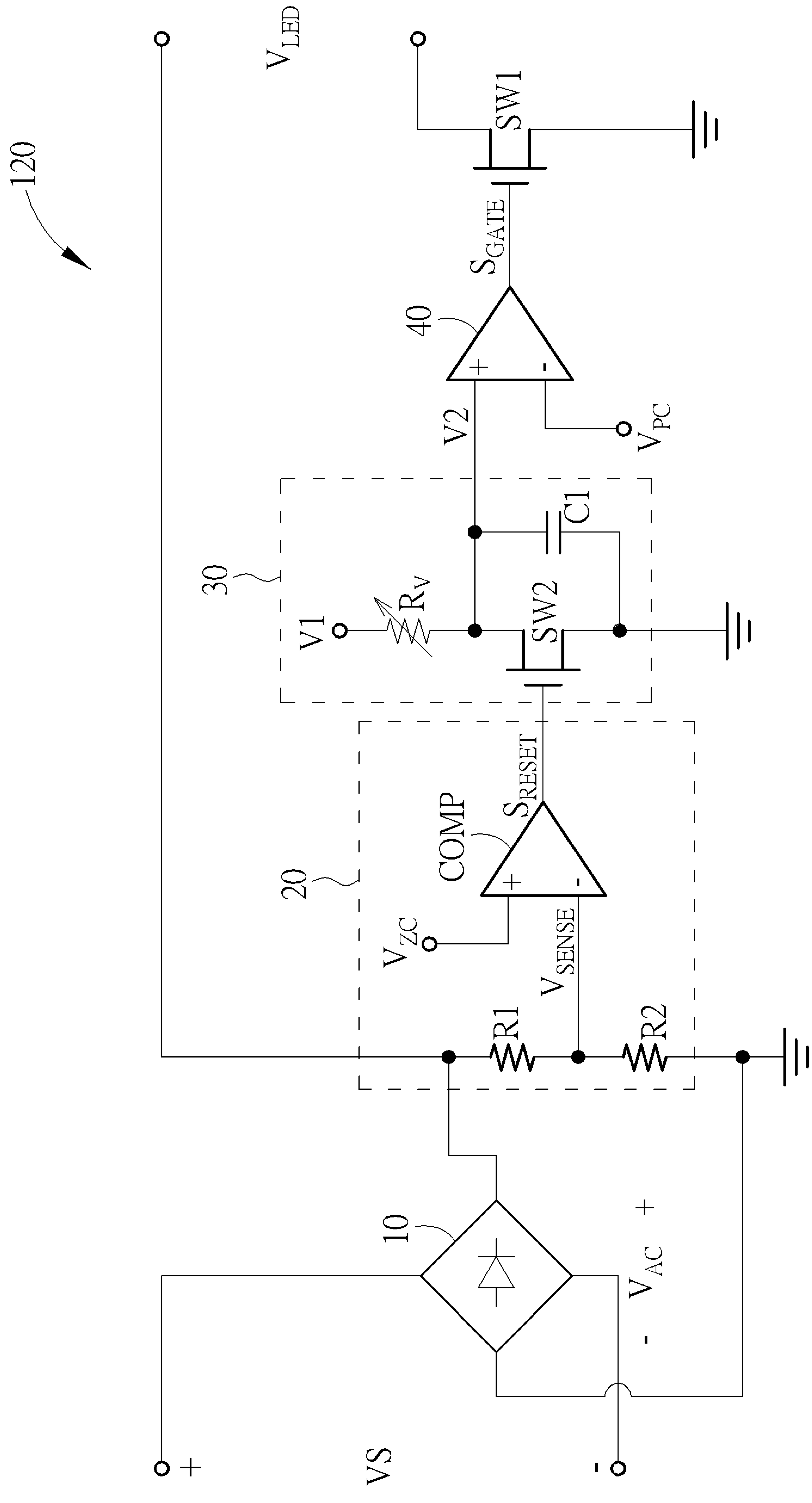


FIG. 1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VLED
SW1
SGATE
40
V2
VPC
30
C1
RV
V1
SW2
20
COMP
SRESET
VZC
VSENSE
R1
R2
10
VAC
VS
+
-

FIG. 2

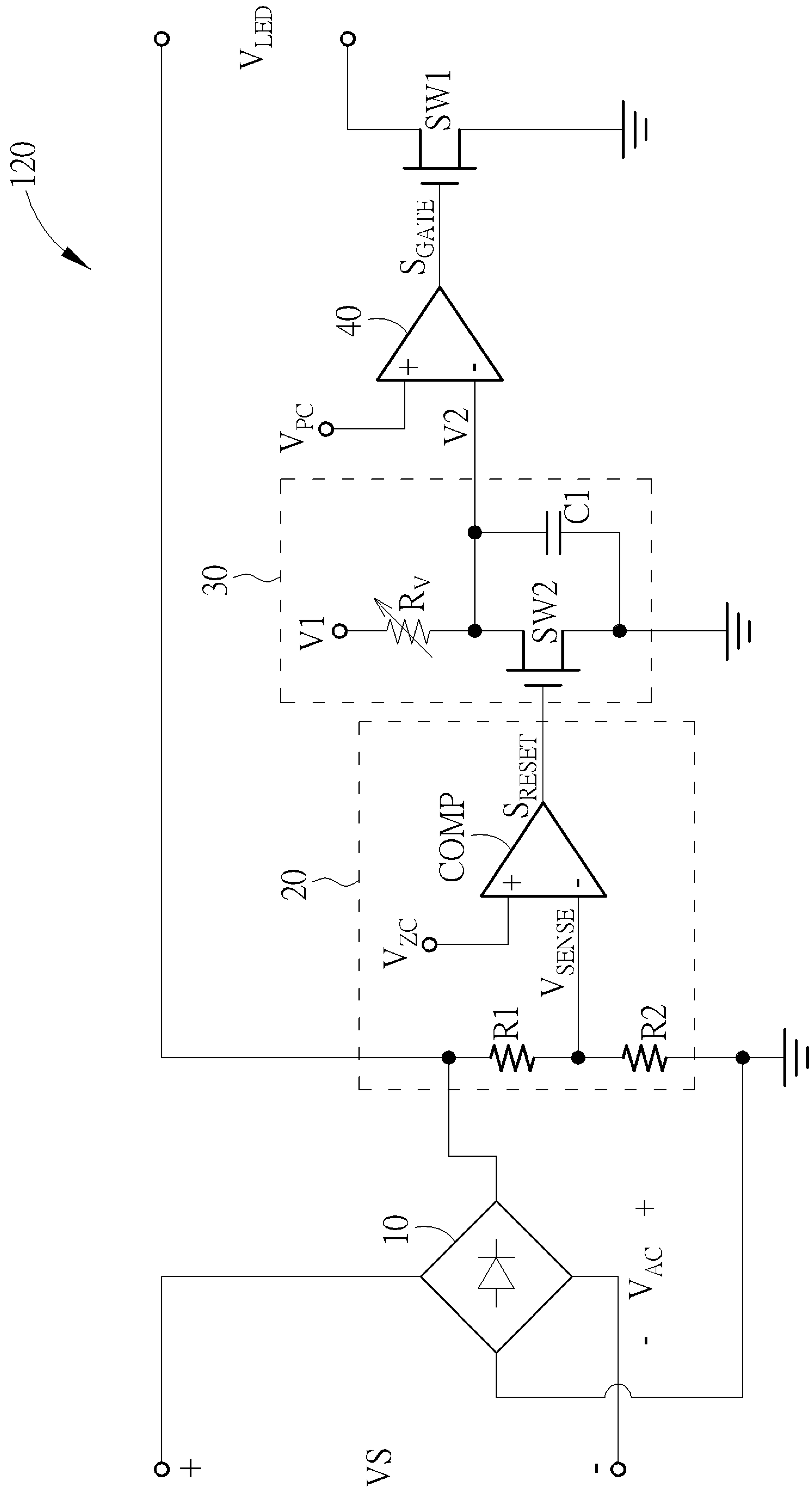
120
V_{LED}
SW1
S_{GATE}
40
V_{PC}
V2
30
V1
R_V
C1
SW2
S_{RESET}
COMP
20
V_{ZC}
V_{SENSE}
R1
R2
10
V_{AC}
+
-
VS
+
-

FIG. 3

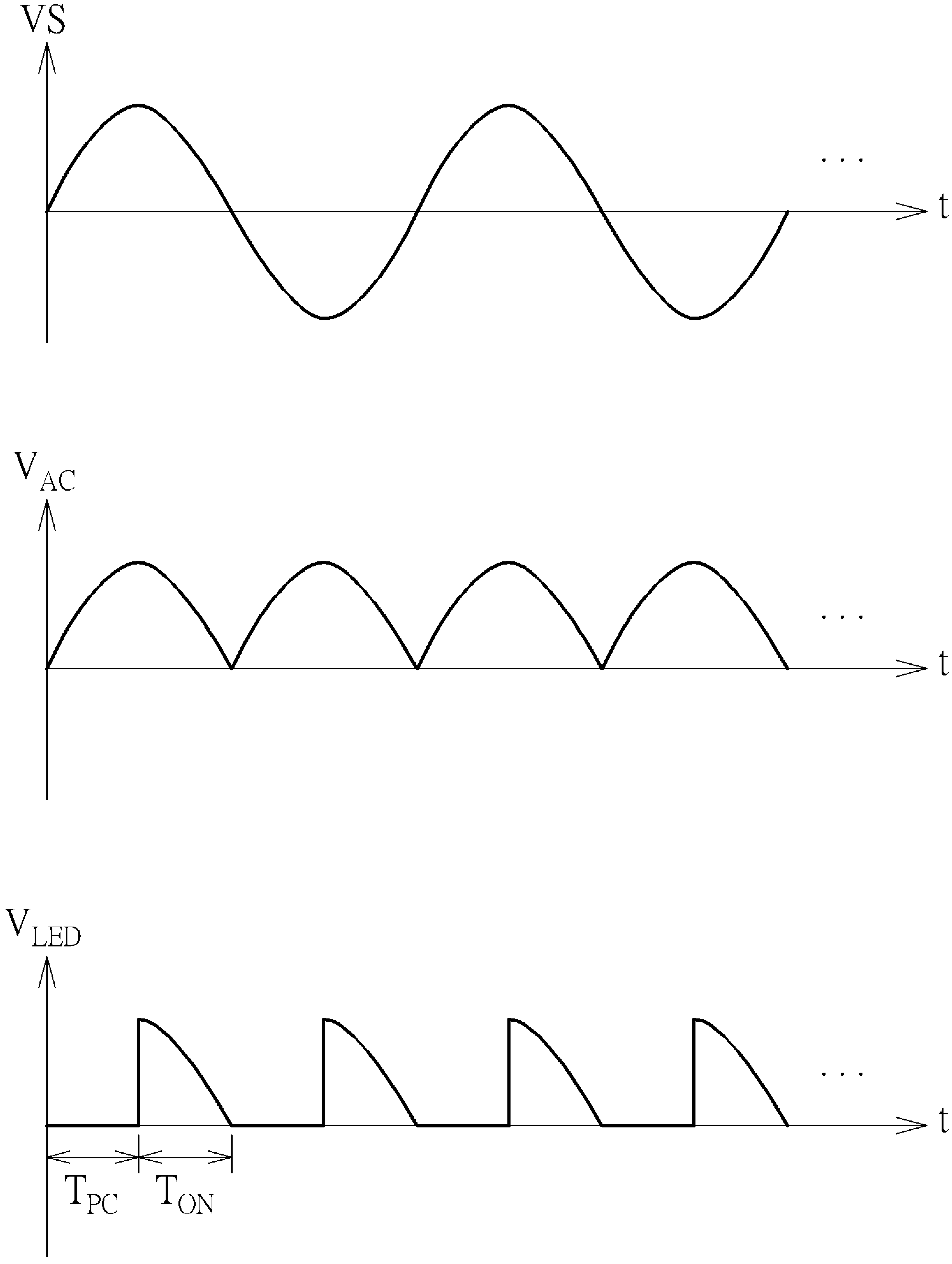

FIG. 4

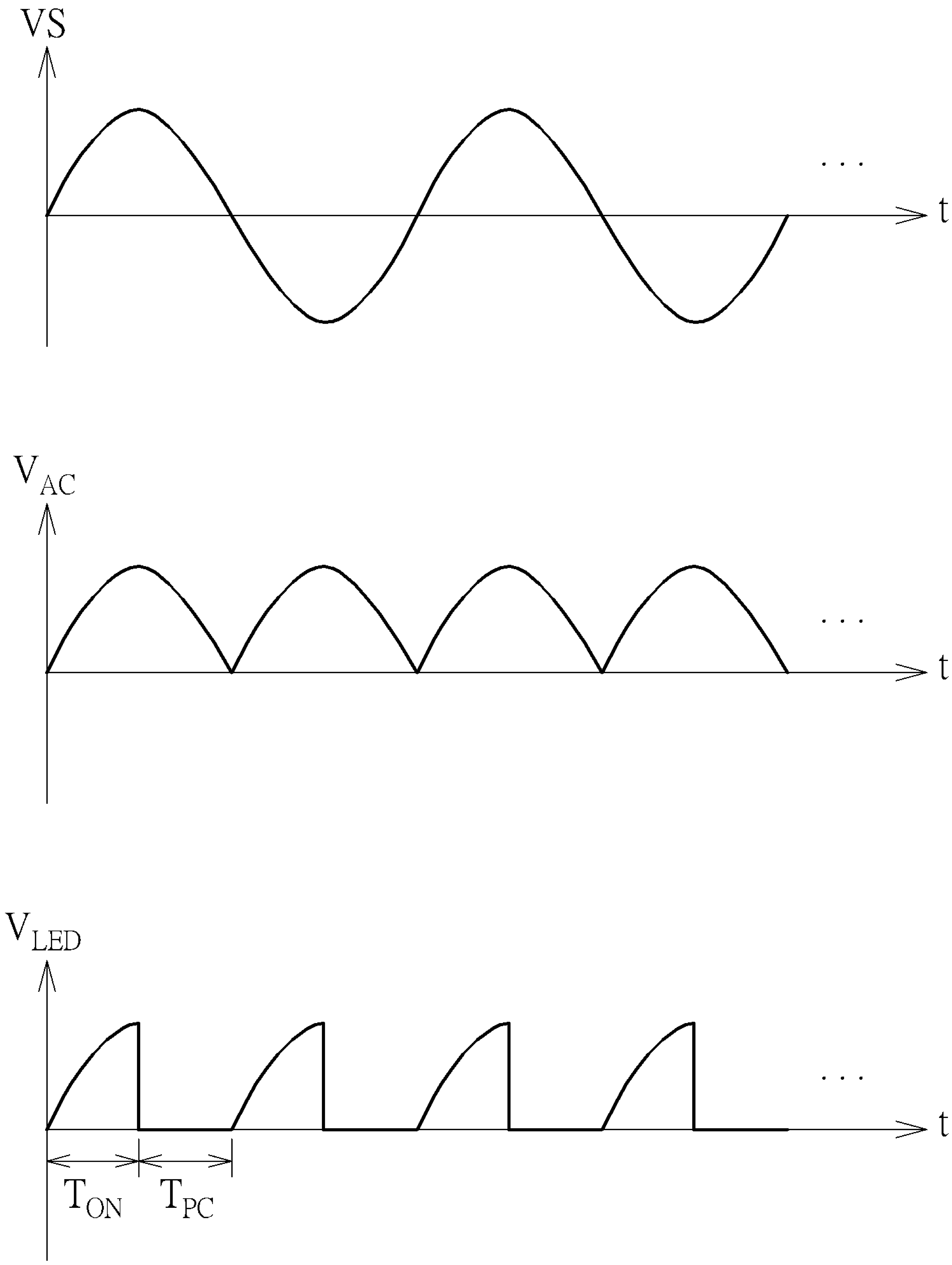

FIG. 5

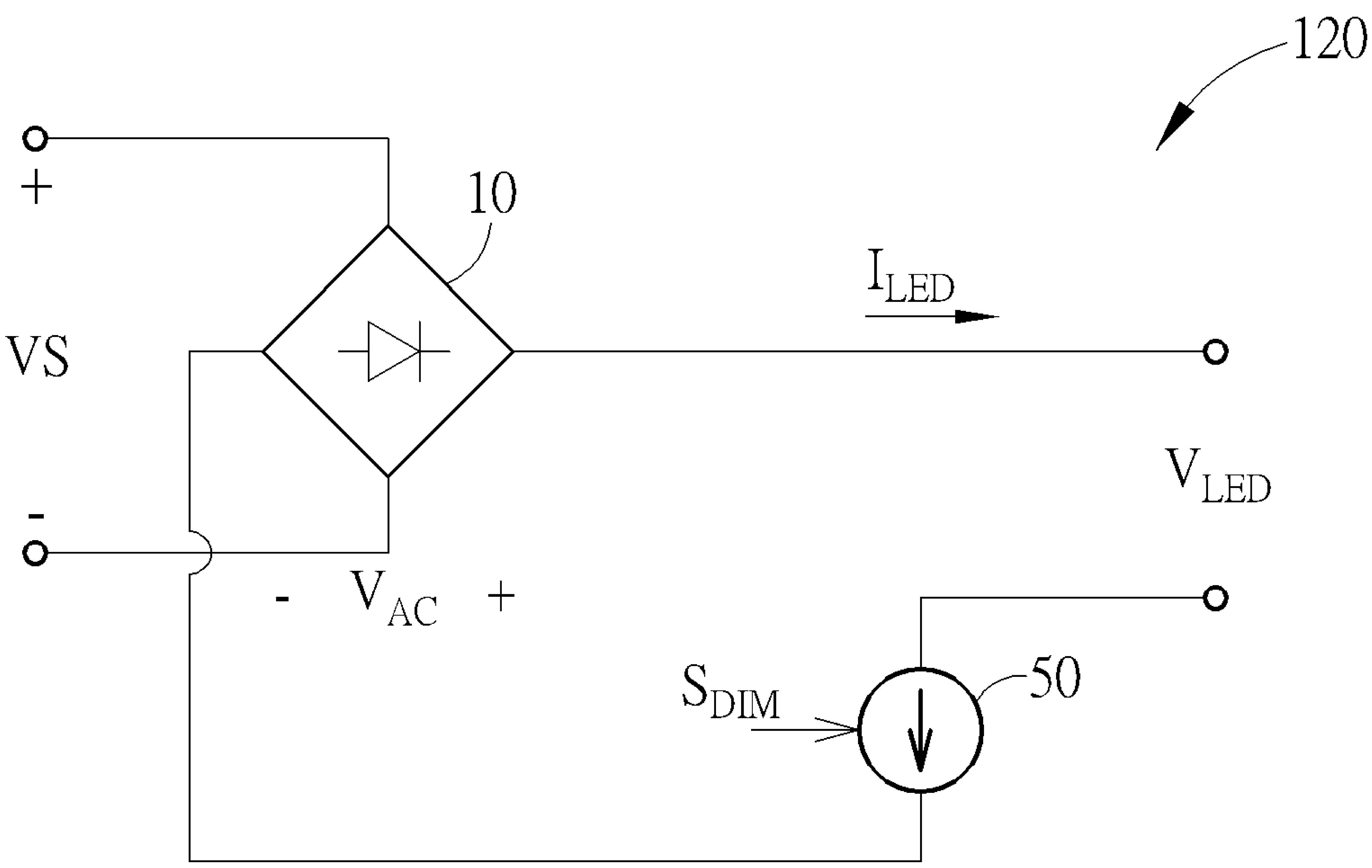

FIG. 6

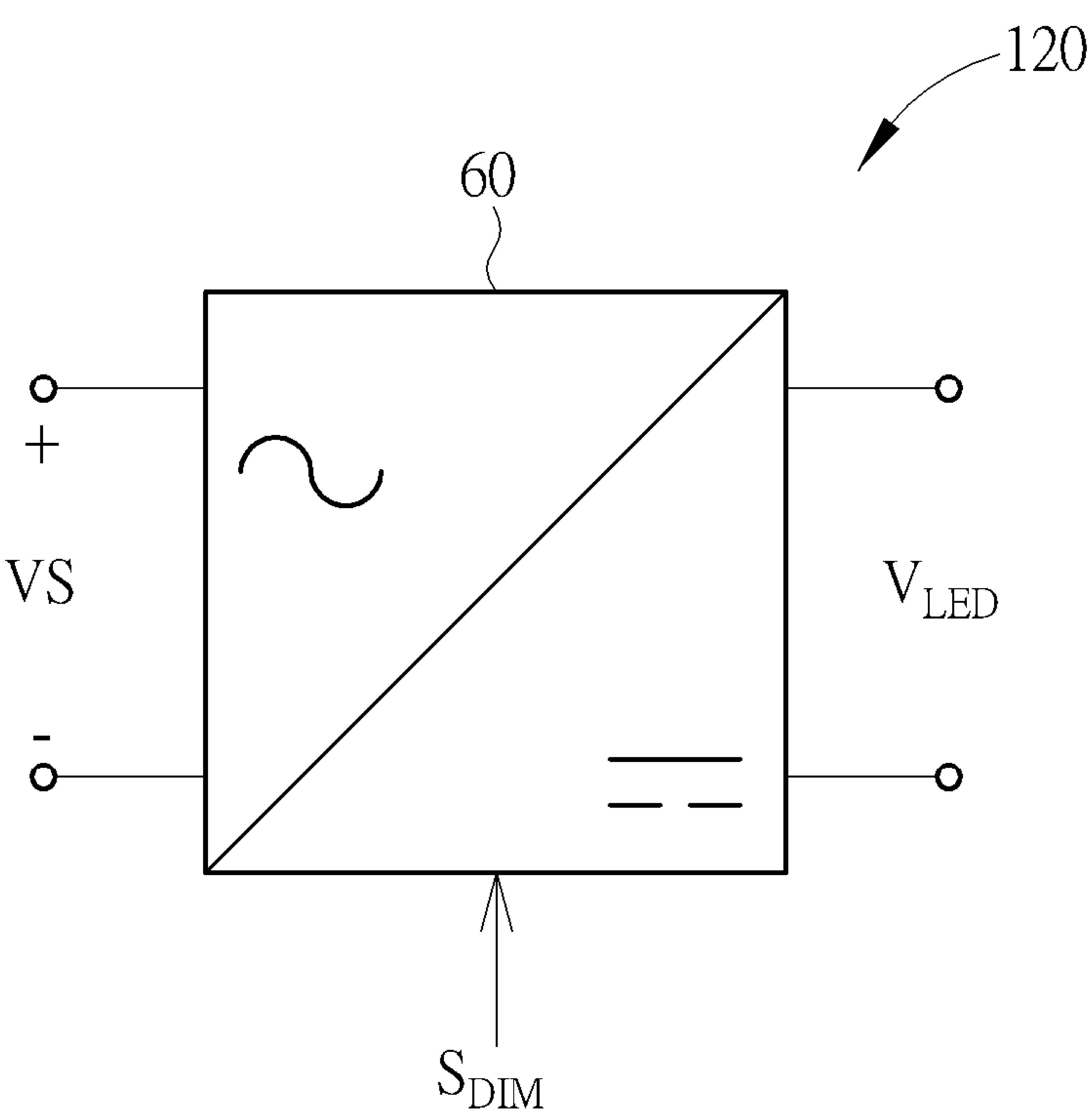

FIG. 7

DIMMER CIRCUIT FOR USE IN LIGHT-EMITTING DIODE LIGHTING SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is related to a dimmer circuit, and more particularly, to a dimmer circuit for use in an LED lighting system without any compatibility issue.

2. Description of the Prior Art

A dimmable light-emitting diode (LED) lighting system often uses a phase-cut dimmer that employ a TRIAC (triode for alternative current) device to regulate the power delivered to an LED lamp by conducting only during a certain period of an alternative-current (AC) voltage supplied to the TRIAC. Unlike other switching elements such as BJTs or MOSFETs, the TRIAC will latch-on once it is energized (after forward current I_F exceeds latching current I_L) and continue to conduct until the forward current I_F drops below a minimum holding current I_H. To maintain the TRIAC in the conducting state, the minimum holding current I_H needs to be supplied to the TRIAC. At turn-on, an LED load presents relatively high impedance, so input current may not be sufficient to latch the TRIAC in the phase-cut dimmer. When the current through the TRIAC is less than the minimum holding current I_H, the TRIAC resets and prematurely turns off the dimmer. As a result, the LED lamp may prematurely turn off when it should be on, which may result in a perceivable light flicker or complete failure in the LED lighting system.

Therefore, a bleeder circuit is used to provide a bleeder current for voltage management and preventing the dimmer from turning off prematurely. However, since the LED lamp is required to conduct the bleeder current at all time, it consumes extra power and lowers system efficiency. In addition, the operation of the dimmer switch and the LED lamp may interfere with each other and cause flicker, especially at low dimming level. Many retrofit LED lamps are sold in two versions: dimmable and non-dimmable. The user needs to choose the correct type of integral LED lamp for use in a dimmable LED lighting system or in a non-dimmable LED lighting system. A non-dimmable LED lamp should not be used in an LED lighting system which employs a prior art phase-cut dimmer as it may cause obvious flickering.

SUMMARY OF THE INVENTION

The present invention provides a dimmer circuit for use in an LED lighting system which includes a power supply circuit and a lamp. The power supply circuit is configured to provide an AC voltage for driving the lamp. The dimmer circuit is configured to adjust a brightness of the lamp according to a dimming signal without the lamp supplying a bleeder current during each cycle of the AC voltage.

These and other objectives of the present invention will no doubt become obvious to those of ordinary skill in the art after reading the following detailed description of the preferred embodiment that is illustrated in the various figures and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a functional diagram of an LED lighting system which adopts a dimmer circuit according to an embodiment of the present invention.

FIG. **2** is a diagram illustrating the implementation of a dimmer circuit in the LED lighting system according to an embodiment of the present invention.

FIG. **3** is a diagram illustrating the implementation of a dimmer circuit in the LED lighting system according to another embodiment of the present invention.

FIG. **4** is a diagram illustrating the operation of the dimmer circuit depicted in FIG. **2** according to an embodiment of the present invention.

FIG. **5** is a diagram illustrating the operation of the dimmer circuit depicted in FIG. **3** according to an embodiment of the present invention.

FIG. **6** is a diagram illustrating the implementation of a dimmer circuit in the LED lighting system according to another embodiment of the present invention.

FIG. **7** is a diagram illustrating the implementation of a dimmer circuit in the LED lighting system according to another embodiment of the present invention.

DETAILED DESCRIPTION

FIG. **1** is a functional diagram of an LED lighting system **100** which adopts a dimmer circuit **120** according to an embodiment of the present invention. The LED lighting system **100** includes a power supply circuit **110**, and a lamp **130**. The power supply circuit **110** may be an alternative current (AC) mains which provides an AC voltage VS having positive and negative periods for supplying operation power to the dimmer circuit **120**. However, the configuration of the power supply circuit **110** does not limit the scope of the present invention.

The lamp **130** may include one or multiple LEDs and an LED driver. The lamp **130** may be a dimmable integral LED lamp or a non-dimmable integral LED lamp. However, the type and configuration of the lamp **130** do not limit the scope of the present invention.

The dimmer circuit **120** is configured to adjust the brightness of the lamp **130** according to a dimming signal S_{DIM}, which may be a pulse-width-modulation (PWM) signal, a direct-current (DC) signal or an inter-integrated circuit (I2C) signal. The dimming operation may be performed by converting the AC voltage VS into a rectified AC voltage V_{AC} whose value varies periodically with time for driving the lamp **30**, by adjusting the phase-cut period of the voltage V_{LED} established across the lamp **130**, by adjusting the level of the voltage V_{LED}, or by adjusting the current I_{LED} flowing through the lamp **130**. In the present invention, since the operation power of the dimmer circuit **120** is supplied by the power supply circuit **110**, the lamp **130** is not required to always conduct a bleeder current. Since the phase-cut operation of the dimmer circuit **120** is independent of that of the lamp **130**, the present dimmer circuit **120** may be applied to all types of lamps including, but not limited to, dimmable integral LED lamps or non-dimmable integral LED lamps without any compatibility issue.

FIGS. **2** and **3** are diagrams illustrating the implementation of the dimmer circuit **120** in the LED lighting system **100** according to embodiments of the present invention. In these embodiments, the dimmer circuit **120** includes a bridge rectifier **10**, a zero-cross detection circuit **20**, a timing circuit **30**, a gate driver **40**, and a switch SW**1**. The bridge rectifier **10** is configured to convert the AC voltage VS into a rectified AC voltage V_{AC} whose value varies periodically with time. The zero-cross detection circuit **20** is configured to detect a zero-cross level of the rectified AC voltage V_{AC}. The timing circuit **30** is configured to determine the length of the phase-cut period of the voltage V_{LED} established across the lamp **130** based on the dimming signal S_{DIM}. The gate driver **40** is configured to output an enable signal S_{GATE} according to the length of the phase-cut period of the voltage V_{LED}. The switch SW**1** is configured to supply the rectified AC voltage V_{AC} to the lamp **130** or cut off the rectified AC voltage V_{AC} from the lamp **130** according to the enable signal S_{GATE}.

In the embodiments illustrated in FIGS. **2** and **3**, the zero-cross detection circuit **20** includes resistors R**1**-R**2** and a comparator COMP. The resistors R**1**-R**2** form a voltage-dividing circuit which senses the level of the rectified AC voltage V_{AC} and provides a corresponding sensing voltage V_{SENSE}. The comparator COMP includes a positive input end coupled to a predetermined reference voltage V_{ZC}, a negative input end coupled between the resistors R**1** and R**2** for receiving the sensing voltage V_{SENSE}, and an output end for outputting a reset signal S_{RESET}. During a cycle when the sensing voltage V_{SENSE} associated with the rectified AC voltage V_{AC} is larger than the zero-cross level defined by the reference voltage V_{ZC}, the comparator COMP is configured to output a reset signal V_{RESET} of a first level for enabling the timing circuit **30**. During a cycle when the sensing voltage V_{SENSE} associated with the rectified AC voltage V_{AC} is not larger than the reference voltage V_{ZC}, the comparator COMP is configured to output a reset signal V_{RESET} of a second level for resetting the timing circuit **30**.

In the embodiment illustrated in FIG. **2**, the timing circuit **30** includes a variable resistor Rv, a capacitor C**1**, and a reset switch SW**2**, while the gate driver **40** may be implemented using a comparator. The gate driver **40** includes a positive input end coupled to the variable resistor Rv and the capacitor C**1**, a negative input end coupled a predetermined reference voltage V_{PC}, and an output end for outputting an enable signal S_{GATE}. The capacitor C**1** is charged by a constant voltage V**1** through the variable resistor Rv, thereby providing a corresponding voltage V**2** at the positive input end of the gate driver **40**. When the voltage V**2** is not larger than the phase-cut reference voltage V_{PC}, the gate driver **40** is configured to output an enable signal S_{GATE} of a third level, thereby turning off the switch SW**1** for cutting off the rectified AC voltage V_{AC} from the lamp **130**. When the voltage V**2** is larger than the phase-cut reference voltage V_{PC}, the gate driver **40** is configured to output an enable signal S_{GATE} of a fourth level, thereby turning on the switch SW**1** for supplying the rectified AC voltage V_{AC} to the lamp **130**. The reset switch SW**2** includes a first end coupled to a first end of the capacitor C**1**, a second end coupled to a second end of the capacitor C**1**, and a control end coupled to receive the reset signal S_{RESET}. As previously stated, during the cycle when the sensing voltage V_{SENSE} associated with the rectified AC voltage V_{AC} is not larger than the reference voltage V_{ZC}, the reset switch SW**2** is turned on by the reset signal S_{RESET} of the first level, thereby shunting the voltage V**1** and allowing the capacitor C**1** to discharge. During the cycle when the sensing voltage V_{SENSE} associated with the rectified AC voltage V_{AC} is larger than the reference voltage V_{ZC}, the reset switch SW**2** is turned off by the reset signal S_{RESET} of the second level, thereby allowing the capacitor C**1** to be charged by the voltage V**1**.

In the embodiment illustrated in FIG. **3**, the timing circuit **30** includes a variable resistor Rv, a capacitor C**1**, and a reset switch SW**2**, while the gate driver **40** may be implemented using a comparator. The gate driver **40** includes a positive input end coupled a predetermined reference voltage V_{PC}, a negative input end coupled to the variable resistor Rv and the capacitor C**1**, and an output end for outputting an enable signal V_{GATE}. The capacitor C**1** is charged by a constant voltage V**1** through the variable resistor Rv, thereby providing a corresponding voltage V**2** at the negative input end of the gate driver **40**. When the voltage V**2** is not larger than the reference voltage V_{PC}, the gate driver **40** is configured to output an enable signal S_{GATE} of a fifth level, thereby turning on the switch SW**1** for supplying the rectified AC voltage V_{AC} to the lamp **130**. When the voltage V**2** is larger than the reference voltage V_{PC}, the gate driver **40** is configured to output an enable signal S_{GATE} of a sixth level, thereby turning off the switch SW**1** for cutting off the rectified AC voltage V_{AC} from the lamp **130**. The reset switch SW**2** includes a first end coupled to a first end of the capacitor C**1**, a second end coupled to a second end of the capacitor C**1**, and a control end coupled to receive the reset signal S_{RESET}. As previously stated, during the cycle when the sensing voltage V_{SENSE} associated with the rectified AC voltage V_{AC} is not larger than the reference voltage V_{ZC}, the reset switch SW**2** is turned on by the reset signal S_{RESET} of the first level, thereby shunting the voltage V**1** and allowing the capacitor C**1** to discharge. During the cycle when the sensing voltage V_{SENSE} associated with the rectified AC voltage V_{AC} is larger than the reference voltage V_{ZC}, the reset switch SW**2** is turned off by the reset signal S_{RESET} of the second level, thereby allowing the capacitor C**1** to be charged by the voltage V**1**.

In the embodiments depicted in FIGS. **2** and **3**, the dimmer circuit **120** is configured to cut the phase of the AC voltage VS so as to disable the lamp **130** during a phase-cut period in a cycle. More specifically, the lamp **130** is only activated during a turn-on period T_{ON} of in cycle of the voltage V_{LED} and is deactivated during a phase-cut period T_{PC} in a cycle of the voltage V_{LED}. Dimming operation can thus be performed by adjusting the length of the phase-cut period T_{PC}.

FIG. **4** is a diagram illustrating the operation of the dimmer circuit **120** depicted in FIG. **2** according to an embodiment of the present invention. FIG. **5** is a diagram illustrating the operation of the dimmer circuit **120** depicted in FIG. **3** according to an embodiment of the present invention. In the embodiment depicted in FIGS. **2** and **4**, the dimmer circuit **120** is configured to perform phase-cut dimming on the rising edge of the rectified AC voltage V_{AC}. In the embodiment depicted in FIGS. **3** and **5**, the dimmer circuit **120** is configured to perform phase-cut dimming on the falling edge of the rectified AC voltage V_{AC}. The length of the phase-cut period T_{PC} of the LED lighting system **100** may be adjusted by adjusting the value of the variable resistor Rv.

FIG. **6** is a diagram illustrating the implementation of the dimmer circuit **120** in the LED lighting system **100** according to another embodiment of the present invention. In this embodiment, the dimmer circuit **120** includes a bridge rectifier **10** and a constant current regulator **50**. The bridge rectifier **10** is configured to convert the AC voltage VS into a rectified AC voltage V_{AC} whose value varies periodically with time. The constant current regulator **50** is configured to limit the current I_{LED} flowing through the lamp **130** to a value indicated by a dimming signal S_{DIM}, which may be a PWM signal, a DC signal or an I2C signal. Dimming operation can be performed by I_{LED} increasing or decreasing the current for adjusting the brightness of the lamp **130**. In another embodiment, the dimmer circuit **120** may further include a capacitor coupled in parallel with the lamp **130** for further reducing flicker. In yet another embodiment, the dimmer circuit **120** may further include a capacitor coupled in parallel with the luminescent devices in the lamp **130** for further reducing flicker.

FIG. **7** is a diagram illustrating the implementation of the dimmer circuit **120** in the LED lighting system **100** according to another embodiment of the present invention. In this embodiment, the dimmer circuit **120** includes an AC-DC converter **60**. The AC-DC converter **60** is configured to convert the AC voltage VS into one of multiple DC voltages indicated by a dimming signal S_{DIM}, which may be a PWM signal, a DC signal or an I2C signal. Dimming operation can be performed by regulating the voltage V_{LED} established across the lamp **130**. In another embodiment, the dimmer circuit **120** may further include a capacitor coupled in parallel with the lamp **130** for further reducing flicker. In yet another embodiment, the dimmer circuit **120** may further include a capacitor coupled in parallel with the luminescent devices in the lamp **130** for further reducing flicker.

In conclusion, the present invention provides a dimmer circuit for use in an LED lighting system. The operation of the dimmer circuit is independent of a lamp of the LED lighting system. Therefore, the luminescent unit is not required to always supply a bleeder current to sustain the dimming operation, thereby reducing power consumption and improving system efficiency.

Those skilled in the art will readily observe that numerous modifications and alterations of the device and method may be made while retaining the teachings of the invention. Accordingly, the above disclosure should be construed as limited only by the metes and bounds of the appended claims.

What is claimed is:

1. A dimmer circuit for use in a light-emitting diode (LED) lighting system which comprises a power supply circuit configured to provide an alternating current (AC) voltage and a lamp driven by the AC voltage, and configured to:

adjust a brightness of the lamp according to a dimming signal without the lamp supplying a bleeder current during each cycle of the AC voltage; and

adjust the brightness of the lamp by adjusting a length of a phase-cut period of a voltage established across the lamp according to the dimming signal, wherein the lamp is deactivated during the phase-cut period;

the dimmer circuit comprising:

a bridge rectifier configured to convert the AC voltage into a rectified AC voltage;

a zero-cross detection circuit configured to detect a zero-cross level of the rectified AC voltage and comprising:

a first resistor and a second resistor coupled in series between the rectified AC voltage and a bias voltage; and

a comparator including:

a positive input end coupled to a first reference voltage associated with the zero-cross level of the rectified AC voltage;

a negative input end coupled between the first resistor and the second resistor for receiving a sensing voltage; and

an output end for outputting a reset signal having a level associated with a relationship between the sensing voltage and the first reference voltage;

a timing circuit configured to determine the length of the phase-cut period according to the dimming signal and comprising:

a variable resistor;

a capacitor having a first end and a second end; and

a reset switch including:

a first end coupled to the first end of the capacitor;

a second end coupled to the second end of the capacitor; and

a control end coupled to receive the reset signal;

a gate driver configured to output an enable signal according to the length of the phase-cut period and comprising:

a first input end coupled to a first voltage via the variable resistor;

a second input end coupled to a second reference voltage; and

an output end for outputting an enable signal having a level associated with a relationship between the second reference voltage and a voltage established at the first input end of the gate driver; and

a switch configured to supply the rectified AC voltage to the lamp or cut off the rectified AC voltage from the lamp according to the enable signal.

2. The dimmer circuit of claim **1**, further comprising a capacitor coupled in parallel with the lamp.

3. The dimmer circuit of claim **1**, wherein:

the lamp includes:

a plurality of luminescent devices coupled in series; and

a current regulator coupled in series to the plurality of luminescent devices; and

the dimmer circuit includes a capacitor coupled in parallel with the plurality of luminescent devices.

* * * * *